Ecology and Conservation of Wolves in a Changing World

Ludwig N. Carbyn
Canadian Wildlife Service
and
Canadian Circumpolar Institute
University of Alberta
Edmonton, Alberta, Canada
and
Department of Renewable Resources
University of Alberta

Steven H. Fritts
U.S. Fish and Wildlife Service
Helena, Montana, USA

Dale R. Seip
British Columbia Forest Service
Prince George, B.C., Canada

Editors

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Methods for Reducing Natural Predation on Moose in Alaska and Yukon: An Evaluation

Rodney D. Boertje, David G. Kelleyhouse, and Robert D. Hayes

We compared several proposed and current methods of reducing natural predation on moose. These included: 1) artificial or "diversionary" feeding of grizzly bears and black bears during the moose calving period; 2) enhancing moose habitat; 3) promoting increases in alternate prey; 4) reducing predator birth rates; 5) conventional public hunting and trapping of predators; and 6) aircraft-assisted wolf harvest. We ranked each method as low, moderate, or high in terms of biological effectiveness, social acceptability, cost-effectiveness, and ease of implementation. Diversionary feeding of bears ranked moderate to high in all categories, except cost-effectiveness. Enhancing moose habitat ranked high in terms of social acceptability and moderate in terms of biological effectiveness, but cost-effective tools are needed. Promoting increases in alternative prey (i.e., caribou) and reducing wolf birth rates ranked low to moderate in terms of biological effectiveness and ease of implementation. Before reducing wolf birth rates, cost-effective, safe, species-specific, and socially acceptable tools need to be developed. Conventional public hunting of bears received high ratings in all categories. Aircraft-assisted wolf harvest also received high ratings, except in terms of social acceptability. A management strategy for reducing predation is outlined.

Introduction

Controlling numbers of wolves (*Canis lupus*), black bears (*Ursus americanus*), and/or grizzly bears (*U. arctos*) to enhance moose (*Alces alces*) populations is an effective strategy when predation is a major limiting factor and moose are below food-limited densities (Gasaway et al. 1983, 1992, Ballard and Larsen 1987, Crête 1987, Van Ballenberghe 1987, Bergerud and Snider 1988). Subarctic wolf-bear-moose systems have higher densities of moose after effective predator control. Also, these systems can support higher hunter harvests than similar systems without predator control (Gasaway et al. 1992). We believe that the long-term viability of wolf and bear populations can be safely protected while practicing localized predator control.

To reduce controversy over predator control, Gasaway et al. (1992) listed five alternatives to predator control by government agencies, and recommended that they be evaluated. We attempt this task with the goal of directing future predator-control research, and management. We evaluated six methods of controlling wolf and/or bear predation: 1) artificial or "diversionary" feeding of bears during calving; 2) enhancing moose habitat; 3) promoting increases in alternate prey; 4) reducing predator birth rates; 5) conventional public harvest of predators; and 6) aircraft-assisted wolf harvest. Details are provided where these techniques are specific to bears or wolves.

Methods

Evaluations were based on four criteria:

1) How biologically effective will the technique be in elevating low-density, predator-limited moose populations or reversing predator-driven declines in moose (Gasaway et al. 1983, 1992)? Substantial population control is needed in these cases (e.g., keeping the spring wolf numbers at 15–40% of the precontrol autumn number for six springs [Gasaway et al. 1983, Farnell and Hayes, in prep.] or an equivalent impact on predation rates). Less intensive predator control may be sufficient to maintain moose at high densities (Gasaway et al. 1992), but is more difficult to implement because no immediate problem is apparent.

2) Are the methods socially acceptable? Social acceptance was evaluated in terms of the likelihood of gaining the political and public support necessary to implement a specific method (Archibald et al. 1991).

3) What is the cost-effectiveness of the technique in terms of operating costs? Other associated costs were not considered.
4) Disregarding social acceptability, can the technique be easily implemented as the demand arises? Managers must have means for achieving population-management objectives. Without accessible tools, managers will fail to meet time-specific objectives.

Evaluation of Techniques

Artificial or "Diversionary" Feeding of Bears during Calving

Feeding bears can potentially increase moose numbers where moose calves are major prey of bears. High bear predation rates (40–58%) have been documented in all Alaska and Yukon studies of radio-collared moose calves (Boertje et al. 1987, Larsen et al. 1989, Schwartz and Franzmann 1989, Ballard et al. 1991a, Osborne et al. 1991). This predation occurs even when moose are well nourished (Gasaway et al. 1992). Baits can be used to attract bears because bears are efficient scavengers. Artificial feeding (hereafter "diversionary" feeding) of bears during moose calving diverts bears from killing calves and enhances calf survival through spring. Bears kill relatively few moose calves after spring (Boertje et al. 1988).

There are three studies in which bears and wolves were artificially fed during moose calving and subsequent moose calf survival was monitored. During May and June 1985, Boertje et al. (1987) air-dropped 12 metric tons of moose carcasses and scrap meat in a 1,000-km^2 area to attract bears for collaring in and around a concentrated moose calving area in east-central Alaska. They observed evidence of grizzly bears, black bears, and wolves feeding at carcass sites. The early winter 1985 calf:cow ratio increased to 53:100 (n = 17 cows) compared with 11–15:100 (n = 26-39, $\underline{P} < 0.005$; Chi Square Test of Independence) during the preceding three years and 26–36:100 (n = 25-27, $\underline{P} < 0.10$) during the following two years when baits were not available to predators. The 1985 response was not evident in three untreated adjacent areas (10–19:100, n = 25-70, $\underline{P} < 0.005$). Although these results suggest that diversionary feeding resulted in increased calf:cow ratios, some increase could have resulted from the slow recovery of bears (four to five days) immobilized with drugs.

In 1990, Boertje et al. (1993b) tested whether diversionary feeding of bears and wolves could improve moose calf:cow ratios in a different 1,650-km^2 study area in east-central Alaska. Twenty-six metric tons of moose carcasses (n = 87 baits at 61 sites, $\bar{x} = 300$ kg) were distributed in three equal proportions 14–15 May, 21–22 May, and 30 May. Median calving date was 21 May. Bears (mostly grizzly bears) and wolves consumed 79% of the baits by 14 June. This was evidenced by disarticulated skeletons and incidental observations of both bears and wolves consuming baits. Moose calf:cow ratios were higher ($\underline{P} < 0.005$) during early winter 1990 (42 calves:100 cows ≥29 months, n = 86 cows) compared with eight prior years ($\bar{x} = 25$, range = 12–38:100, n = 51–75) and 1990 untreated sites (11–27:100, n = 85–204).

In 1991, the experiment was repeated in the same 1,650-km^2 study area with only 16 metric tons of moose carcasses (Boertje et al. 1993b). During early winter 1991, moose ratios were 32 calves:100 cows ≥29 months (n = 100) in the treated area, compared with 16–37:100 (n = 58–225) in untreated adjacent areas. The smaller amount of bait may have been insufficient to significantly enhance calf survival, considering the size of the area and number of bears present.

Biologists in the state of Washington have six years of experience with diversionary feeding of black bears to protect forest plantations (Ziegltrum 1990). A commercial bear ration was developed and field-tested. Feeding has partially replaced lethal control of bears. Bears were fed a complete, sugar-based pelleted ration *ad libitum* from mid-March through June to divert them from stripping bark and feeding on exposed sapwood. Feeding proved more cost-effective and more socially acceptable than lethal control of bears. The program has been expanded each year.

Despite success with diversionary feeding, this technique ranked moderately effective as a predator-management tool (Table 1) for two reasons. First, diversionary feeding could increase predator numbers by enhancing predator physical condition, productivity, and juvenile survival, and by temporarily attracting predators from adjacent areas. This would confound predator-prey management problems. Feeding could occur for only two to four weeks to minimize effects on predators and maximize benefits to moose. Also, feeding levels could be adjusted to merely supplant the nutrition naturally obtained from killing neonates, if studies experimented with different levels of preferred food.

Second, although feeding can be successful in reducing early bear predation on moose calves, wolves may compensate with increased predation later in the year. For example, Hayes et al. (1991) found that wolves removed 64% of the moose calves in a low-density population during each of two winters in southern Yukon. However, most studies have documented that most moose mortality occurs during the first three weeks of life (Boertje et al. 1987, 1988; Larsen et al. 1989; Ballard et al. 1991a).

Diversionary feeding ranked high in social acceptability (Table 1) because no killing of predators was involved (Arthur et al. 1977). Public attitudes have been favorable in Alaska when predators were fed moose carcasses. Disfavor may arise if costly commercial food sources are used. Disfavor may also arise if bears are perceived as conditioned or dependent on the feeding program, therefore feeding time should be minimal (three to four weeks).

Diversionary feeding was ranked low in cost-effectiveness and moderate in terms of ease of implementation (Ta-

Table 1. Relative evaluation of six methods of increasing predation-limited moose populations in areas suited to the particular methods, based on four criteria.

	Diversionary feeding of bears during calving	*Enhancing moose habitat*	*Allowing increases in alternate prey*	*Reducing wolf birth rates*	*Conventional public hunting of bears*	*Aircraft-assisted wolf harvest*
Biological effectiveness	Moderate	Moderate	Low	Low to moderate	Moderate to high	High
Social acceptability	High	High	Moderate to high	Moderate	High	Low
Cost-effectiveness	Low	Low to high	High	Low to Moderate	High	Moderate to high
Ease of implementation	Moderate	Low	Low	Low to Moderate	High	High

ble 1). It is expensive and difficult to acquire, store, and distribute bait that is environmentally safe, socially acceptable, inexpensive, and effective. Local availability of suitable bait may determine the choice of foods. Commercial bear food (e.g., from Washington at $2/kg) may be too expensive unless manufactured close to delivery sites. Twenty metric tons of bait were needed to divert grizzly bears (16 bears/1,000 km^2, [Boertje et al. 1987]) from moose calves in a 1,650-km^2 area in east-central Alaska. Using commercial food sources, annual bait costs may total $40,000, and transportation costs would escalate if off-road areas were selected for feeding programs.

In the 1985 (Boertje et al. 1987) and 1990 (Boertje et al. 1993b) programs, train-killed moose were collected during winter at the railroad's expense. These moose were stored under sawdust and distributed at the U.S. military's expense during helicopter training missions. In 1991, starved moose and those killed by traffic were collected by volunteer groups in Fairbanks, Alaska (Boertje et al. 1993b). Moose were distributed using Alaska Department of Fish and Game (ADF&G) vehicles, a DeHavilland Beaver aircraft, and a riverboat. These subsidized operations were affordable ($4,000–$9,000 /year), but large numbers of moose carcasses are seldom available. Alternative foods need to be tested. Development of chemical attractants for coyotes (*C. latrans*) (Green 1987, Scrivner et al. 1987) may be useful in researching techniques to attract and detain bears.

Enhancing Moose Habitat

Three mechanisms are listed that could decrease the impact of predation, but further research is needed to test the widespread existence of these mechanisms. First, burning has been associated with improved moose nutritional status (Schwartz and Franzmann 1989), which may decrease the vulnerability of individual moose to predation. However, Gasaway et al. (1992) concluded that moose nutrition is a minor factor affecting low-density moose populations in most of Alaska and Yukon. Second, the killing or hunting efficiency of predators may decline in burns or commercially logged areas. Predators may be disadvantaged by the fallen timber in burns. Also, moose are often scattered randomly throughout large burns in interior Alaska and Yukon. In contrast, in unburned habitat, moose density is highest in narrow zones of shrubs, e.g., riparian or subalpine areas, where predators can travel easily and predictably find moose. Third, increased moose density following burning has been related to increased productivity (Schwartz and Franzmann 1989), and to increased time moose spend in burns (Peek 1974, Gasaway et al. 1989). These factors could indirectly reduce the impact of predation on a moose population by increasing local moose:predator ratios (Gasaway et al. 1983, Schwartz and Franzmann 1989).

Evidence that moose density may increase substantially as a result of burning is indicated by a moose density of 417 moose/1,000 km^2 in the large 26-year-old Teslin burn in southern Yukon (2,515-km^2 survey area [Gasaway et al. 1992]). This density is three times higher than the average density in 20 areas (> 2,000 km^2 each) where wolves and bears were similarly lightly harvested and moose were the primary prey (Gasaway et al. 1992). Moose densities in these other areas ranged from 45 to 269 moose/1,000 km^2. No other area had the uniformly extensive, ideal habitat of the Teslin burn.

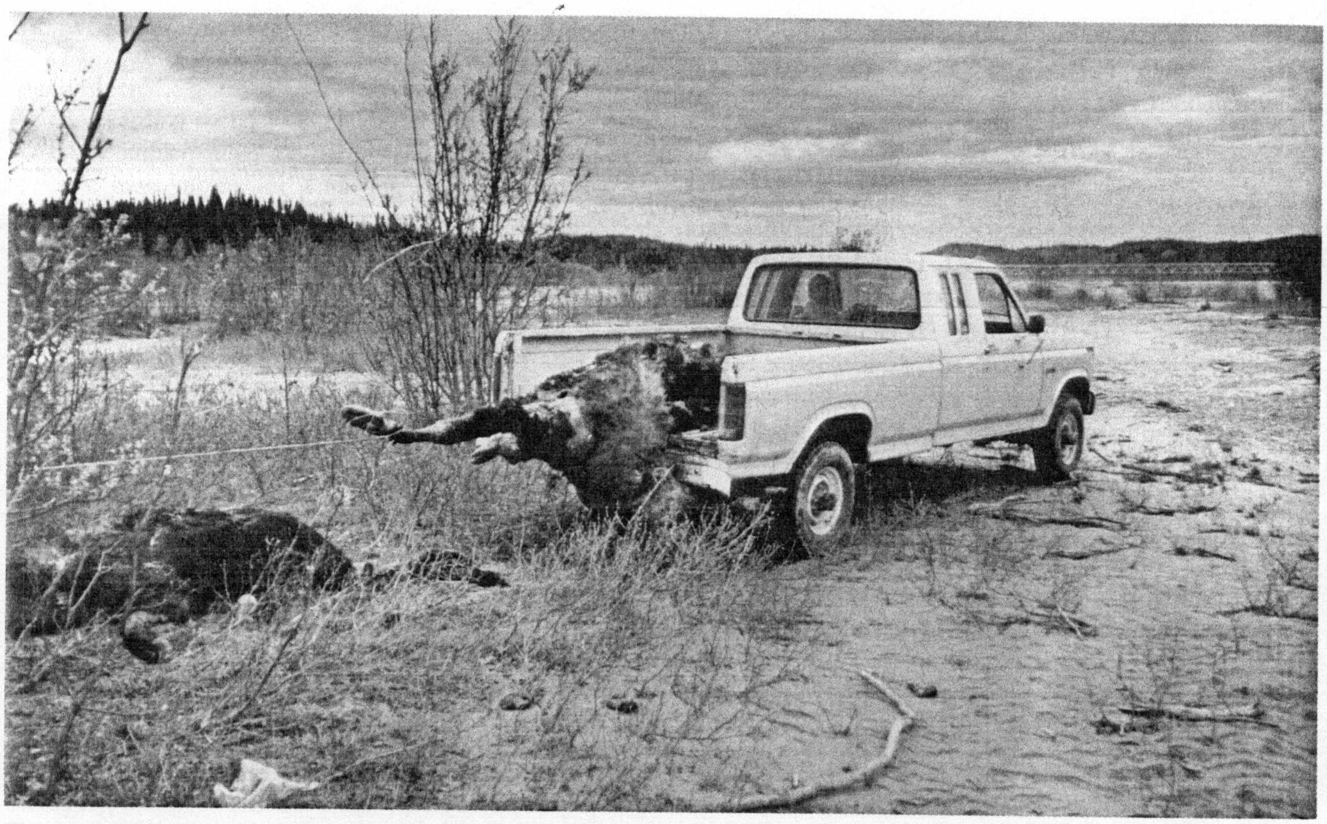

Fig. 1. *Moose carcasses being distributed by Alaska Department of Fish and Game personnel to feed bears. Moose killed by trains or traffic in winter were collected and stored under sawdust. The carcasses were distributed during moose and caribou calving seasons. Studies concluded that, by feeding bears, one can successfully divert bears from killing newborn moose calves (Photo: R. D. Boertje).*

Social acceptability of habitat enhancement ranked high (Table 1) relative to other techniques, although decreased air quality from burning has been unfavorable. Cost-effectiveness of this method would be variable depending on the methods of habitat enhancement. Prescribed burns have huge costs associated with containment ($500/km^2 in Alaska). Funds from commercial logging could help pay for ways to encourage browse species favored by moose.

Habitat enhancement of large areas (> 2,000 km^2) is not currently available as a wildlife management tool. The ADF&G has statutory mandates to manage wildlife, but no statutory authority to enhance habitat for wildlife. Wildfires are usually contained by land managers, regardless of opportunities for enhancing moose habitat. Prescribed burning and extensive logging of moose habitat are in their infancy in Alaska and Yukon, but may increase in the near future.

Managers and researchers need to be capable of implementing coordinated, long-term studies of predator-moose-habitat relationships, pre- and posthabitat enhancement, before habitat enhancement can be evaluated as a tool to decrease predation on moose.

Promoting Increases in Alternative Prey

Gasaway et al. (1992) proposed allowing caribou (*Rangifer tarandus*) to increase as a method for increasing moose numbers. Caribou have escaped predation regulation without strong human intervention (Skoog 1968). Moose, in contrast, require substantial human intervention to escape predation limitation by both wolves and bears in Alaska and Yukon (Coady 1980, Yesner 1989, Gasaway et al. 1992). Decreased predation on moose may follow large increases in caribou (Holleman and Stephenson 1981, Ballard et al. 1987:38, Boertje et al. 1993b), but exceptions occur when caribou change movement patterns (Boertje et al. 1993b). Wolf numbers correlate with ungulate biomass (Keith 1983, Fuller 1989, Gasaway et al. 1992). Therefore, it may be difficult to reduce total predation on moose when caribou increase, unless measures to prevent increases in wolf populations are implemented.

This method is viewed as a waiting process, not a tool, and therefore ranked low in terms of ease of implementation (Table 1). Hunters may have to forego some opportunity to hunt caribou, while waiting for moose to increase. This lowers the potential social acceptability of this method (Table 1).

Reducing Predator Birth Rates

Surgery, implants, inoculations, and oral administration of drugs have been used to reduce predator birth rates (Stellflug and Gates 1987, Orford et al. 1988). However, wolf preda-

Fig. 2. *Moose in a 24-year-old burn on the Kenai Peninsula, Alaska. Ideal moose habitat can occur 10 to 30 years after wildfire in Alaska, and moose density is often relatively high in these habitats. (Photo: J.L. Davis)*

tion and movement studies indicate that birth control may have low to moderate effectiveness in reducing predation for several reasons. First, the maintenance of wolf pairs in an exploited population can result in significantly higher per capita wolf kill rates (Hayes et al. 1991). Second, ingress of subadult wolves into wolf control areas may offset the results of birth control. For example, in a highly exploited wolf population in south central Alaska, 28% of 135 wolves dispersed, and 22% of dispersers were accepted into existing packs (Ballard et al. 1987). Immigrating wolves may be accepted at a greater rate in an area where birth control is practiced. Also, lightly harvested adjacent populations may have a greater percentage of dispersing wolves than observed in the highly exploited wolf population in south-central Alaska. Ingress would be less significant if treated wolf populations were insular or peninsular. Translocation of young wolves combined with sterilization of adult pairs may significantly reduce predation.

Birth control for grizzly bears is not recommended because of inherently low reproductive rates. Female bears have lower immigration rates than wolves (Ballard et al. 1987, Reynolds 1990), therefore bear populations would be slow to recover from birth control. Reducing birth rates of black bears may have some application in specific circumstances, because black bear densities and productivity are higher than those of grizzly bears (Reynolds 1990, Schwartz and Franzmann 1991).

Social acceptability of predator birth control was ranked moderate (Table 1). This evaluation was based on responses received following a press release that mentioned birth control as a potential predator-control technique in Alaska. The cost-effectiveness of birth control was ranked low to moderate, because of high implementation costs (Table 1). Implementation of the most common birth control techniques (surgery, implants, or inoculation) requires immobilization of individual predators, which is extremely difficult and expensive in remote areas of Alaska and the Yukon. For example, recent costs to collar a wolf pack or a grizzly bear averaged $2,000 in a remote, largely forested study area in east-central Alaska.

Distributing baits containing chemosterilants is an alternative to immobilizing individual predators. The use of chemicals, however, requires registration by the Environmental Protection Agency, and preregistration research costs may total millions of dollars. Chemosterilants would not be approved if found to impair nontarget species, such

Fig. 3. *Caribou are secondary prey of wolves in most of central Alaska; moose are the primary prey. Waiting for caribou numbers to increase in hopes that predation on moose will decline is not a viable strategy for attaining management objectives. When caribou increase in numbers, they often move beyond the range of resident wolf packs and leave the resident moose with relatively high predation rates. (Photo: J.L. Davis)*

as wolverines (*Gulo gulo*). Species-specific delivery systems will be required, thereby necessitating further development costs.

Conventional Public Hunting and Trapping

"Conventional public harvest" of wolves and bears is defined as hunting and trapping exclusive of aircraft-assisted or snowmachine-assisted hunting. As a predator-control technique, conventional harvest received high ratings in social acceptability, cost-effectiveness, and ease of implementation, in part because of minimal agency involvement (Table 1). Conventional harvest of wolves has effectively reduced or stabilized wolf numbers below food-limited levels near populated areas (e.g., on the Kenai Peninsula [Peterson et al. 1984] and north of Anchorage [Gasaway et al. 1992:42]). Harvest of black bears using bait likewise has reduced black bear densities near Fairbanks (Hechtel 1991). Attempts have been made in limited remote areas in Alaska to encourage public harvest of wolves and grizzly bears to stimulate increases in ungulates.

The ADF&G promoted trapper-education programs in two remote areas to stimulate interest in wolf trapping and snaring and to increase success rates. This promotion included trapper workshops and the production and distribution of a video on canid trapping techniques. A nonprofit native organization provided wolf snares to trappers in select villages. Total numbers of wolves trapped did not increase in these areas (Pegau 1987, Nowlin 1988). The inherent wariness of wolves, poor access, and a lack of economic incentives for trapping wolves contributed to the failure of this program to increase wolf harvest.

In contrast, hunters have increased grizzly bear harvest sufficiently to reduce grizzly bear densities in two remote Alaska study areas. Reported annual harvests averaged about 8–9% in an east-central Alaska (Boertje et al. 1987, Gasaway et al. 1992) and a central Alaska study site (Reynolds 1990). These harvest rates can cause long-term, slow declines averaging about 2% annually (Reynolds 1990). Methods used to encourage grizzly bear harvest in east-central Alaska included: liberalizing hunting regulations on grizzly bears, increasing the number of hunters by increasing opportunity to hunt male ungulates, and encouraging hunters to harvest grizzly bears through information

Fig. 4. *Conventional public harvest of bears can be used as a management tool to reduce predation on moose calves. At the same time, managers can protect the viability of bear populations. (Photo: R.L. Zarnke)*

and education. Liberalized hunting regulations included: lengthening the hunting season, deleting a resident grizzly bear tag (fee) requirement, and increasing the bag limit to one bear/year, as opposed to the usual bag limit of one bear/four years. The harvest of sows accompanied by cubs and yearlings was not authorized.

In the east-central Alaska study site, moose were below food-limited densities, and grizzly predation was a major factor limiting the moose population (Boertje et al. 1987, Gasaway et al. 1992). Moose calves per 100 cows during fall increased in this area, coincidental to potential declines in grizzly numbers. Grizzly harvests averaged 8% annually during 1982–88 (Boertje et al. 1987, Gasaway et al. 1992). Assuming this harvest rate equates to a 2% annual decline (Reynolds 1990), the grizzly population declined 14% by 1989. Moose calves per 100 cows ≥ 2 years old increased from a range of 19–27 ($\bar{x} = 23$) during 1982–1988 to 32–48 ($\bar{x} = 38$; $\underline{P} < 0.05$, Mann-Whitney two-sided test) during 1989–1991. Other factors did not favor increased moose calf survival. For example, wolf densities were higher ($\underline{P} = 0.026$, Student's t-test) during fall 1989–1991 ($\bar{x} = 7.3$ wolves/1,000 km^2) than fall 1982–1988 ($\bar{x} = 5.9$ wolves/1,000 km^2), alternative prey (caribou) declined, and snow depths were greater during late winter 1990 and 1991 (Boertje et al. 1993a).

Field studies on the effects of bear harvest on moose calf survival are needed where: 1) moose are below food-limited densities; 2) bear predation is a major factor limiting moose; and 3) bear reductions are publicly sanctioned. Managers need to know the degree to which reductions in bears affect moose calf survival in different ecosystems. Managers also need to know whether decreasing trends in numbers of bears harvested per unit effort will provide sufficient information to manage bears (e.g., without expensive bear population estimates). Increased bear harvests are not recommended: 1) where bear predation accounts for a small fraction of total predation; 2) where moose are near food-limited densities, unless additional moose harvest is desired; or 3) in coastal areas where bears are the primary species of management concern.

Aircraft-Assisted Wolf Harvest

Public and agency wolf harvests using aircraft have proven effective at reducing annual fall wolf numbers and stabilizing populations below food-limited levels (Gasaway et al. 1983, 1992, Ballard et al. 1987, Farnell and Hayes, in prep.

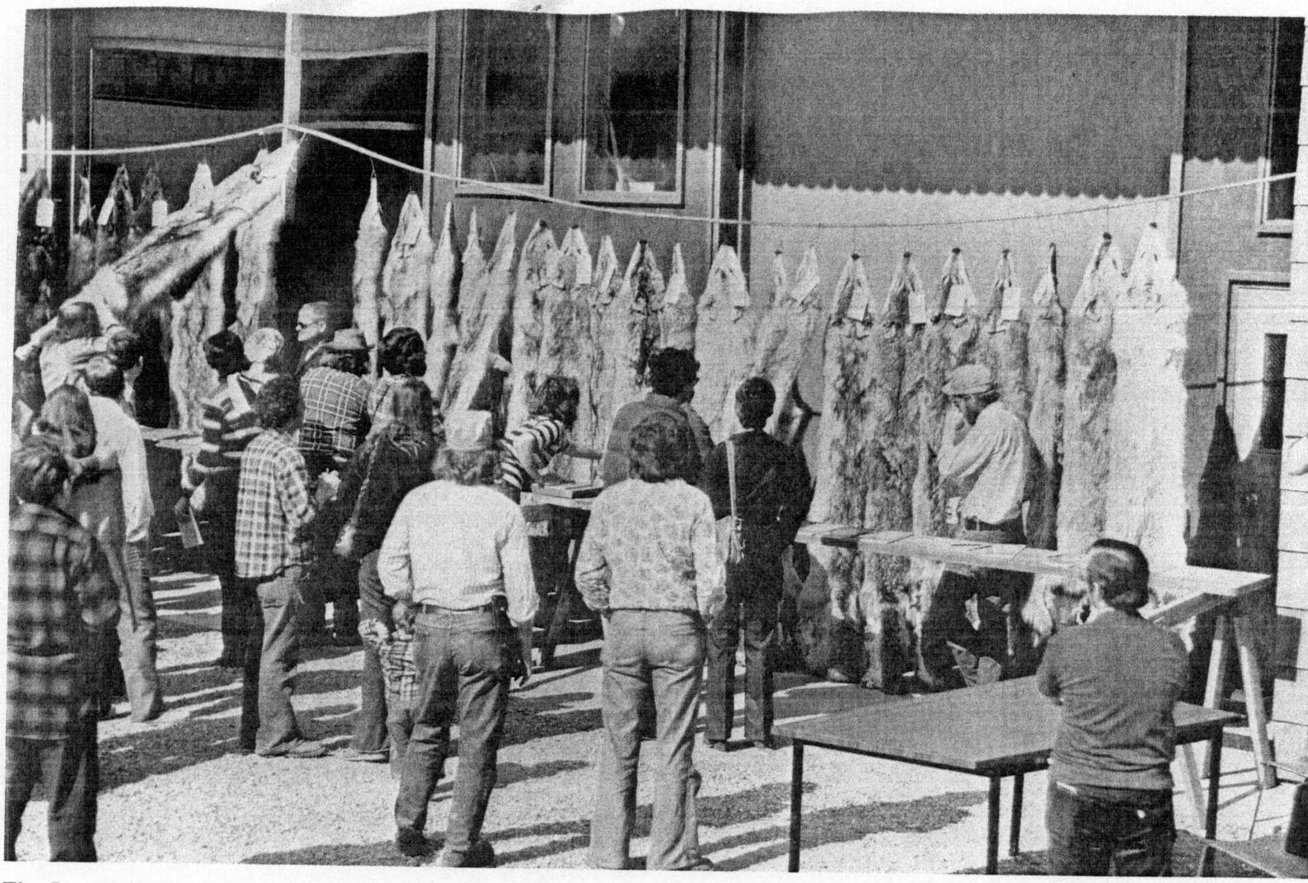

Fig. 5. *Wolf hides collected during agency wolf control programs have been auctioned to the public. (Photo: ADF&G)*

Boertje et al. 1996). The public has reduced wolf numbers using light, fixed-wing aircraft in areas with high proportions of unforested, open terrain and suitable snow conditions for tracking and landing. Large portions of interior Alaska north of the Alaska Range are ill-suited to this method. The use of aircraft was discontinued where wolves were extremely vulnerable (e.g., portions of northern and northwestern Alaska). In these areas, snowmachines replaced aircraft as a tool to effectively reduce or regulate wolf numbers.

During the 1980's, wolves were regularly held below food-limited densities by public, aircraft-assisted wolf harvest in only a portion of south-central Alaska (Ballard et al. 1987). Wary wolves are able to avoid aircraft-assisted harvest in more forested areas of Alaska. The primary method has been land-and-shoot harvest in which the hunter lands near the wolf before shooting. Shooting from the air was discontinued in 1972 in Alaska, except under state permit in specific areas (Harbo and Dean 1983, Stephenson et al. this volume). In November 1992, Alaska's Board of Game passed regulations allowing the use of aircraft only for wolf "control" not wolf "harvest." Agency wolf control programs have involved aerial shooting from light, fixed-wing aircraft and helicopters. Radiotelemetry has occasionally been used in these programs to help locate packs, especially where tracking conditions were poor. Only one ADF&G aerial wolf control program survived legal proceedings and reviews for four years of effective wolf control (> 60% reduction of pre-control wolf numbers). The ADF&G shot 18–67 wolves annually during four years in this area (Gasaway et al. 1983). The program was followed by a 5-6 fold increase in moose numbers (Boertje et al. 1996). A similar, seven-year agency wolf control program in east-central Yukon (1983-1989) also resulted in elevated moose numbers (Farnell and Hayes, in prep.).

Aircraft-assisted wolf harvest is viewed as having the lowest social acceptability of the six methods evaluated in Table 1. Harbo and Dean (1983) and Stephenson et al. (this volume) trace the history of court cases reflecting this low social acceptability. Indeed, the major motivation for investigating alternative techniques is the low social acceptability of this method (Gasaway et al. 1992).

Cost-effectiveness of this method is relatively high. For example, the public can effectively reduce wolves to low densities without agency assistance in portions of south-central and western Alaska. In interior Alaska and southern Yukon, operating costs of agency-sponsored aerial wolf reductions have ranged from about $500 to $1,000 per wolf, yet returns have been high in terms of additional ungulate harvest (Boertje et al. 1996, R. Farnell, Yukon Fish and Wildl. Br., pers. commun.). Administrative and educational costs associated with aircraft-assisted wolf harvest are high, in part because of low social and political acceptability. Social and political factors also affect how easily managers can implement this tool.

Management Strategy

Several recommendations are given for circumstances where the local public has sanctioned predator control to meet management objectives for moose. These are: 1) rank areas based on suitable habitat, overall demand, management and research capabilities, and social and economic costs; 2) evaluate the suitability of several combined techniques for a specific area; 3) educate and inform the general public, as well as public advisory groups; and 4) adopt a formal process for approving area-specific wildlife management plans in areas with and without anticipated predator control. It is essential that the public be informed about trade-offs between social- and biological-based management decisions.

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